Contents

1. OBJECTIVE

The purpose of this document is to outline health and safety management requirements for the safe handling, transport, fabrication, storage and disposal of nanoparticles utilised or generated during research or teaching and learning activities at RMIT.

2. BACKGROUND

Nanotechnology generally refers to engineered structures, materials and systems that operate at a scale of 100 nanometres (nm) or less. Nanoparticles can occur naturally (viruses, bushfire smoke), incidentally (diesel, combustion exhausts), and through engineering processes (carbon nanotubes).

Nanoparticle materials are of significant scientific interest as some material properties can change at this scale. Such changes are challenging our understanding of hazards and our ability to anticipate, recognise, evaluate and control potential health and safety risks.

Generally, the types of hazards nanomaterials may present include physiological effects due to exposure through inhalation, ingestion, and skin penetration. Physiological effects depend on the size, dose, reactivity, form and structure of the nanomaterial.

Also, nanoparticulate forms of some materials show unusually high reactivity, especially for fire, explosion and in catalytic reactions.

Adverse chemical reactions with incompatible materials and environmental contamination must also be considered.

3. SCOPE

This process applies to all RMIT, globally.

NOTE – Referenced legislation applies to Australian jurisdictions only. RMIT campuses in other jurisdiction must refer to local applicable legislation, where available.

This document is primarily intended to provide guidance for small scale laboratory projects where there is a requirement to manage the health and safety concerns associated with the following:

- Engineered nanomaterials that are intentionally created in contrast with natural or incidentally formed with dimensions of less than 100nm. This definition excludes biomolecules and nanoscale forms of radiological materials
- Nanoparticles that are dispersible particles having two or three dimensions greater than 1nm and less than 100nm and which may or may not exhibit a size related property
- Unbound engineered nanoparticles (UNP) which are engineered nanoparticles that are not contained within a matrix that would be expected to prevent the nanoparticles from being separately mobile and therefore a potential source of exposure (an engineered nanoparticle dispersed and fixed within a polymer matrix and incapable of becoming airborne would be ‘bound’, while such a particle suspended as an aerosol or in a liquid would be ‘unbound’)
- Precursors, intermediates and wastes used during, or resulting from synthesising such nanomaterials.

4. WHAT MUST GO RIGHT?

Should this process be implemented appropriately by RMIT, the expected outcomes – known as ‘what must go right’ – will be that:

- Nanotechnology risks are systematically identified, assessed and controlled to eliminate or reduce the risk of harm.
- All staff, students, researchers and third parties who undertake work, learning and/or research activities involving nanoparticles understand the associated risks and the controls to be implemented.
- All staff, students, researchers and third parties understand how to handle, transport, fabricate, store and dispose of nanoparticles.

5. PROCEDURE / IMPLEMENTATION

5.1. Risk Management

Risks associated with nanoparticles are to be managed in accordance with the ***HR – HSW-PR09 – HSW Risk Management***. The following provides information on control measures that must be considered and where practicable must be implemented to manage the risk associated with working with nanomaterials and nanoparticles.

In general terms, the choice of this control approach should include consideration of the level of risk involved. For example:

- Low risk – Use general ventilation
- Medium risk – Use local engineering control e.g., local exhaust ventilation (LEV)
- High risk – Use process containment
- Critical risk – Seek specialist advice

5.1.1. Elimination

Whilst it is difficult to eliminate the risk associated with working with nanomaterials or nanoparticles, effective process design can make a major contribution to preventing exposures in the work and learning environment.

5.1.2. Substitution

While the unique chemical and physical properties/characteristics of nanoparticles are likely to limit possibilities for straightforward substitution of one nanoparticle type for another, substitution of a known hazardous nanomaterial to one which is less hazardous, but is still suitable for the task, should be considered. Other substitution methods such as replacing dry powder with wet paste or slurries to minimise generation of uncounted particles, as well as substituting the need for large quantities of nanomaterials to smaller amounts should also be applied.

5.1.3. Isolation & Engineering Controls

In general, source enclosure should be effective for capturing airborne engineered nanomaterials, based upon what is known about nanoscale particle motion and behaviour in air. In case of a leak from enclosed processes, primary nanoparticles can escape and disperse through the room. How much nanoparticle aerodynamic properties resemble those of gases is yet to be determined. However, from known relationships, a 10nm particle is expected to have a diffusion coefficient considerably lower than a nitrogen or oxygen molecule of around 0.3 nm size.

Facility isolation can be considered by dedicating a laboratory for nanomaterials work only. Where an existing laboratory may be used for nanomaterials and other work, a dedicated work zone should be created where possible and separate nanomaterials by using physical barriers, curtains with seals, or similar. In such cases a negative pressure work area may be required.

Local isolation of nanomaterials using various engineering systems should also be applied. Projects or processes involving the generation of nanoparticle aerosols and nanoparticles in suspension must be performed in a chemical fume hood, externally ducted biological safety cabinet, or enclosed glove box to limit the inhalation exposure potential. Maximum protection for the environment and the staff member, researcher and/or student will be achieved through using a Class III Biological Safety Cabinet (BSC) designed for work with highly infectious microbiological agents and for the conduct of hazardous operations. Class II BSCs are not suitable for handling nanoparticles because they re-circulate up to 70% of their air inside the cabinet.

Control banding can be applied when considering engineering risk controls for working with nanomaterials. This approach is useful for materials where there are no established Workplace Exposure Standards (WES) which is currently the situation with respect to all nanomaterials except Titanium Dioxide ($TiO2$). Control banding is a qualitative strategy for assessing and managing hazards associated with chemical exposures in the workplace. In relation to nanomaterials a key component of control banding is the ability to categorise easily the toxicity of substances using information that is readily available, in this case material safety datasheet information for bulk size particles. This information links hazard groupings (A, B, C, D), hazard classification (e.g., whether a material is toxic, corrosive etc), hazard statements and guideline control level (8-hour Time Weighted Average) and control recommendations for each group. In the case of nanomaterials, the variables that are considered are hazard group, level of dustiness of material used and amount used.

Currently, for engineered nanoparticles and most particles of nanostructured materials there is limited understanding of the level of risk involved therefore in this environment where there is risk uncertainty, a precautionary risk management approach must apply based upon the **As Low As Reasonably Achievable** (**ALARA**) principle.

If the use of closed containment options is not possible, then it is best to avoid the formation of dusts or aerosols. However, in some processes, it is impossible to avoid airborne release of dusts and aerosols. Source capture of these pollutants e.g., by using local exhaust ventilation, (LEV) is then the method of choice to prevent airborne propagation of these products in the work environment. Where possible the exhaust air should be filtered through a High Efficiency Particulate Air (HEPA) - H14 system to remove airborne nanomaterials before venting to outside the building.

Fume hoods are the most frequently used engineering control for the handling of nanomaterials. Where such hoods are used consideration should also be given to the use of exhaust filtration systems e.g. HEPA filters, non HEPA filters, wet scrubbers and sub-micrometre rated cartridge filters that block nanoparticles to less than 10 nm.

General ventilation by dilution in the work/learning environment can draw contaminants outward, and if it is the only engineering control utilised, might allow significant exposure to nanoparticles. If the use of LEV for open processes is not practicable, then it might be preferable to use displacement ventilation to reduce background levels, where fume is extracted at roof or ceiling level. Vented air must never be recirculated unless it has passed through a HEPA filter.

Filtration also plays an important role in the control of exposure to airborne particles. HEPA filters could be used in engineering control systems to clean air before returning it to the work/learning environment, or before discharge to the atmosphere. Such filters are usually classified as mechanical filters. Current knowledge indicates that a well-designed exhaust ventilation system with a HEPA filter should effectively remove nanoparticles. It should be noted however, that only a limited amount of work has been done to quantify the performance of filters against particles in the nanometre size range.

Current methods for certification of HEPA filters do not routinely require testing at particle sizes below 100 nm. The US Department of Energy's standard, DOE HEPA Filter Test Program, an internationally recognised standard, requires that each filter is tested at an aerosol diameter of 300 nm aerodynamic diameter and that the particle collection efficiency is greater than 99.97%. Given the dimensions and physical properties of nanoparticles, an approved HEPA filter should have a filtration efficiency greater than 99.97% for most nanoparticles.

5.1.4. Administrative Controls

Administrative controls that focus training and effective and documented procedures must be considered and implemented during a laboratory scale nanoparticle research project or teaching/learning activity. Such controls constitute an additional approach to supplement engineering approaches but are not a substitute for engineering approaches. Some administrative controls that must be considered include:

- Developing standard operating procedures for handling, transport, storage and disposal of nanomaterials
- Providing known information to staff, student and researcher on the hazardous properties of the nanomaterial precursors or products
- Education/training of staff, student and researcher on the safe handling of nanomaterials
- Restricting access to areas by using signs or placards to identify areas of nanoparticle research
- Transport dry nanomaterials in closed containers
- Handle nanoparticles in suspension on disposable bench covers
- Always perform nanoparticle aerosol generating activities, such as weighing dry powdered nanomaterials, in a fume hood, externally ducted biological safety cabinet, or glove box
- Clean the nanomaterial work area daily at a minimum with a HEPA-vacuum or wet wiping method
- Modification of work/learning/research practices
- Minimising the number of exposed people
- Ensure effective personal hygiene measures
- Use of preventive maintenance, which minimises the risk of unscheduled interruption of activity while assuring safer operations
- Wet cutting should be used wherever possible, and
- Good housekeeping.

5.1.5. PPE

Monitoring the work and learning environment will determine the effectiveness of control approaches described above. A risk assessment must be completed to determine personal protective equipment (PPE) requirements. For commercially available nanomaterials, the Safety Data Sheet will stipulate the type of PPE that is to be used regarding body, hand, eye and respiratory protection.

5.2. Risk Management Summary

Control	Description
Elimination	Eliminating worker exposure to nanomaterials wherever possible throughout the manufacturing and handling of nanomaterials.
Substitution	Substitution of a known hazardous nanomaterial to one which is less hazardous, but is still suitable for the task, should be considered.
Isolation & Engineering controls	In addition to considering health and safety regulatory requirements and the work / study / research requirements, safe layouts must be designed to eliminate situations involving risks for the process and for the workers. SafeWork Australia's position is that "*current control measures such as enclosure and local exhaust ventilation should be effective for capturing airborne nanoparticles, given what is generally understood about the motion and behaviour of nanoparticles in air*."
Administrative controls	Administrative means of control must always be used in addition to, and not in place of, engineering controls. Administrative controls may include the reduction of work and learning periods, modification of work and learning practices, personal hygiene measures,

	housekeeping and preventative maintenance will also limit the occupational exposure risks.
Personal protective equipment	PPE is normally used as a last resort and only when all other means of control have been implemented. Please note that it is unclear how effective currently available PPE will be with regards to preventing exposure to nanomaterials. Airway protection equipment, used in locations where nanomaterials are produced in the form of dust, must be extremely efficient. Experimental work indicates equipment may enable the possible filtration down to four nanometres in diameter. A full-face mask with high performance filters is recommended. Protective clothing and gloves may limit exposure of the skin to nanomaterials.

5.3. Working Safely with Nanomaterials

5.3.1. Exposure

Throughout research there are uncertainties with potential routes of exposure, movement of nanomaterials once they enter the body and the body's response to nanomaterials. As a result of their exceptionally small size nanoparticles are thought to be able to move past the protective mechanisms of the body that usually intercept and process particles of a larger size.

Inhalation is considered to be the primary route by which nanomaterials in the form of free, unbound, airborne particles could enter the bodies of staff, researchers and students. Nanoparticles or nanomaterials used in laboratory experiments will likely be in one of three forms: a powder, in suspension, or in a solid matrix. The form of the nanoparticles or nanomaterial will play a large role in the exposure potential.

Ingestion could occur by swallowing the mucous that traps and clears particles deposited in the airways, by swallowing contaminated food or water, or by oral contact with contaminated surfaces or hand.

Dermal absorption could occur when skin is exposed to nanomaterials during manufacture or use or by contact with contaminated surfaces. The extent of the ability of nanomaterials to penetrate intact skin and cause adverse effects is unknown. In addition, the effect of flexing the skin has yet to be fully explored as has the role of solvents in skin uptake.

Staff, researchers and students using nanomaterials must take measures to prevent the risk of routes of entry even if the extent of the risk is largely unknown.

5.3.2. Fire and Explosion

Since the effectiveness of methods for nanoparticle fire, explosion and catalysis prevention and control are yet to be suitably evaluated, the same principles applying to the management of fine powders, dusts or dusty materials are to be adopted. Particular care is to be taken in the case of easily oxidisable metallic dust.

Explosion protection measures have been described for dust dispersions and for hazardous quantities of larger sized materials and can be potentially applied to the handling of potentially explosive nanoparticles. For the handling of flammable nanoparticles, following these types of measures is also recommended. For reactive or catalytically active nanoparticles, contact with incompatible substances must be prevented.

Fire prevention must also consider existing regulations, especially electrical requirements regarding intrinsic safety.

The selection of an extinguishing agent must consider the compatibility or incompatibility of the material with water. Some metallic dusts react with water to form, among other things hydrogen. Chemical powder extinguishers must be made available to extinguish burning metallic dust powders. Any staff, researchers and students who are responsible for extinguishing these types of fires must be suitably trained and competent to do so.

Industry has adopted the following when working with potentially explosive nanomaterials:

- Anti-static shoes and mats being used in areas where the materials are handled. Such shoes reduce the build-up of static charge which could potentially ignite the materials.
- A distillation system for evaporating solvent from a colloidal dispersion being housed within an explosion-proof enclosure. This enclosure was designed with concern for the potential for those particular nanomaterials to be explosive.

5.3.3. Carbon Nanotubes

Carbon Nanotubes are a type of nanomaterial. They are hollow nanofibres, having two similar external dimensions on the nanoscale (1-100nm), with the third dimension significantly larger. They consist of curved graphene layers — graphene consists of a single layer of carbon atoms in a honeycomb structure. A nanometre is one-billionth of a meter; to put this in context, a sheet of paper is about 100,000 nanometres thick. Carbon Nanotubes can be bio persistent and have the potential to exist as fibre-like structures.

Exposure to Carbon Nanotubes is to be recognised as consistence with any type of nanomaterial. The risk management strategies outlined above in section ***Risk Management*** must be applied to ensure health and safety risks are suitability controlled.

5.4. Health Monitoring

Health monitoring is to be undertaken in accordance with ***HR – HSW-PR47 - Health Monitoring***. There are no workplace exposure limits or health monitoring requirements for nanomaterial in Australia. Safe Work Australia, however, have suggested workplace exposure limits for titanium dioxide (0.3mg/m3) and carbon nanotubes (0.001mg/m3). It is preferable to prevent potential exposure with robust control measures rather than applying a health monitoring regime.

5.5. Emergency Management

Refer to local RMIT Campus Emergency Response Procedures under hazardous materials spills or leaks. Spill management will vary depending on the type of nanomaterial used. In the event of a spill, a systematic approach must be taken in accordance with the manufacture’s safety data sheet and local spill management guidelines.

5.6. Storage

Nanomaterials must be stored in accordance with their SDS, where available. Nanomaterial should be stored in a double container, where practical, to help reduce accidental exposure risks. Powders must only be kept in sturdy sealed containers to avoid inadvertent chemical reactions or accidental dispersion of materials if the container breaks. Nanomaterials must not be stored with incompatible chemicals and in incompatible containers. Aliquoted nanomaterial must be labelled as per ***HR - HSW-PR32 – Hazardous Substances*** prior to storage.

5.7. Waste Management

Nanomaterial waste must be treated as a hazardous chemical waste and disposed of in accordance with ***HR - HSW-PR32-WI01 – Storage, Use and Disposal of Hazardous Substances*** process and local waste management procedures.

5.8. Transport

Commercially acquired nanomaterials will be suitably packaged for safe transport. Transporting nanomaterials in original packaging is preferred on campus and between campuses. A risk-based approach must be taken when transporting internally (RMIT) manufactured nanomaterials. It is recommended that such nanomaterials are transported in wet or slurry form and double contained, closed and sturdy containers.

5.9. Program Evaluation

In order to ensure that this process continue to be effective and applicable to RMIT, the program will be reviewed regularly by the HSW Team and relevant stakeholders. Conditions which might warrant a review of the process on a more frequent basis would include:

- an injury or near miss resulting from exposure to nanomaterials
- incidents related to nanomaterials
- changes to legislation and associated standards
- worker or workplace concern.

Following completion of any review, the program will be revised and, if necessary, updated in order to correct any deficiencies.

6. Responsibilities

6.1. Senior Leaders

- Ensure there are resources available to implement this process in their area of control
- Ensure mechanisms are in place for effective and meaningful consultation regarding matters relating to this process.
- Monitor and review HSW performance, relating to this process, across their area of responsibility to ensure all hazards, incidents and near misses are managed in accordance to GSM.
- Ensure the maintenance of adequate facilities and safe systems of work relating to this process.
- Ensure staff, students, researchers and third parties are provided with necessary information, instruction, supervision, and training relating to nanotechnology.

6.2. Operational Leaders

- Ensure there are resources available to implement this process in their area of control
- Ensure and implement mechanisms for effective and meaningful consultation regarding matters relating to this process.
- Participate in the risk management processes for health and safety matters relating to nanotechnology and engage subject matter experts as required within their area of responsibility.
- Monitor and review HSW performance, relating to this process, across their area of responsibility to ensure all hazards, incidents and near misses are reported, investigated and actioned in accordance to the GSM.
- Ensure and implement processes that will maintain adequate facilities and safe systems of work relating to this process.
- Ensure and implement processes that will provide the necessary information, instruction, supervision, and training relating to nanotechnology for staff, students, researchers and third parties.

6.3. Technical Staff

- Participate in the implementation of this process in their area of responsibility, including the maintenance of adequate facilities and safe systems of work
- Participate in effective and meaningful consultation regarding matters relating to this process.

- Taking reasonable care for their own health and safety when working and/or learning with nanomaterials.
- Taking reasonable care to ensure their acts or omissions do not adversely affect the health and safety of other persons as a result of working and/or learning with nanomaterials
- Actively participating in risk management processes for nanotechnology and engage subject matter experts as required.
- Promptly informing and reporting to their manager/ supervisor hazards, incidents and near misses as a result of working and/or learning with nanomaterials
- Participating in meetings, instruction and training relating to nanotechnology activities
- Pass on any information to others to protect themselves or others from risk of injury or illness as a result of working and/or learning with nanomaterials

6.4. Staff/students/researchers/third parties

- Taking reasonable care for their own health and safety when working and/or learning with nanomaterials.
- Taking reasonable care to ensure their acts or omissions do not adversely affect the health and safety of other persons as a result of working and/or learning with nanomaterials
- Complying with the requirements detailed in this process
- Actively participating in risk management processes for nanotechnology and engage subject matter experts as required.
- Promptly informing and reporting to their manager/ supervisor hazards, incidents and near misses as a result of working and/or learning with nanomaterials
- Participating in meetings, instruction and training relating to nanotechnology activities
- Pass on any information to others to protect themselves or others from risk of injury or illness as a result of working and/or learning with nanomaterials

6.5. HSW Team

- Provide advice on nanotechnology safety where required.
- Regularly review this process in consultation with relevant stakeholders
- Develop and report on KPIs relevant to this process
- Monitor compliance with this process and report on outcomes

7. Definitions

Defines any key terms and acronyms relating to the process where they apply.

Term / acronym	Definition
Agglomerate	Group of particles held together by relatively weak forces, including van der Waals, electrostatic and surface tension forces.
Aggregate	Heterogeneous particle in which various components are not easily broken apart.
Control Banding	A strategy that groups workplace risks into control categories based upon combinations of hazard and exposure information.
High Efficiency Particulate Filter	Is a type of air filter that satisfies certain standards of efficiency such as those set by the United States Department of Energy (DOE)
Nanoparticle	In nanotechnology, a particle is defined as a small object that behaves as a whole unit in terms of its transport and properties. Nanoparticles are sized between 1 and 100 nanometres.

Nanotechnology	Areas of technology where dimensions and tolerances in the range of 0.1nm to 100nm play a critical role.

8. Related Documents

Lists the supporting and related Processes and Guidance Material, Legislative references, Australian and International Standards etc. that may be useful references for process users

- HR – HSW-PR09 – Risk Management
- HR - HSW-PR32 – Hazardous Substances
- HR - HSW-PR32-WI01 – Storage, Use and Disposal of Hazardous Substances
- HR – HSW-PR47 - Health Monitoring
- ISO/TR 12885:2018 - Nanotechnologies - Health and safety practices in occupational settings relevant to nanotechnologies
- NanoSafe Australia (www.ausnano.net)
- National Nanotechnology Initiative (USA) (www.nano.gov/)
- "***A Review of The Potential Occupational Health & Safety Implications of Nanotechnology***" – Safe Work Australia (ASCC) - July 2006. Archived.
- ***"Classification of Carbon Nanotubes as Hazardous Chemicals"*** – Safe Work Australia – October 2012
- ***"Safe Handling and Use of Carbon Nanotubes"*** – Safe Work Australia – March 2012